

LONG-TERM IMPACTS OF HIGHWAY CONSTRUCTION ON MILL CREEK, ONTARIO

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James N. Bowlby
Ontario Ministry of Natural Resources
Lake Ontario Fisheries Assessment Unit
c/o Assembly Hall, Prince Edward Heights Complex, Picton, Ontario K0K 2T0

Jacob G. Imhof
Ontario Ministry of Natural Resources
10670 Yonge Street, Richmond Hill, Ontario L4C 3C9

Raymond B. Biette and Douglas P. Dodge
Ontario Ministry of Natural Resources
Fisheries Branch, Toronto, Ontario M7A 1W3

C.H. Oliver, Editor



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ABSTRACT

Bowlby, J. N., J. G. Imhof, R. M. Biette, and D. P. Dodge. 1987. Long-term impact of highway construction on Mill Creek, Ontario. Ont. Fish. Tech. Rep. Ser. No. 24. 12 p.

To determine any long-term impacts related to the construction of the Hanlon Expressway at a tributary of Mill Creek, Ontario, we collected data on fish and invertebrate populations, water quality, and bed load during summer, 1985, and compared them with original data collected by Mathers (1978b) from 1972 to 1976 (before, during, and after the construction). Bed load remained elevated immediately downstream from the construction site. A continuing source of the bed load material is marl beds that were exposed during relocation of the west branch of Mill Creek. Material from the relocation channel has covered the stream bed for 250 m downstream from this channel. This material is moving downstream at the rate of about 25 m yr^{-1} and is expected to reach mainstream Mill Creek by the year 2010. Invertebrate density was lower in the stream area overlaid by bed load marl. Biomass of brook trout (*Salvelinus fontinalis*) remained about one-half pre-construction levels. Although brook trout density remained constant at this location, the average size of trout is now smaller and these impacts appear to be caused by the material from the west relocation channel that has reduced the quality of habitat for fish and invertebrates. Farther downstream, fish biomass has increased to pre-construction levels, but brown trout (*Salmo trutta*) have replaced some brook trout. Sodium and Cl levels have increased two- to three-fold at all stations; part of this increase appears to be related to the use of deicing salt in the vicinity of the highway construction. Nutrients, heavy metals, and other water quality variables showed no changes related to highway construction.

Keywords: highway construction, impacts, fish, invertebrates, bed load

LONG-TERM IMPACTS OF HIGHWAY CONSTRUCTION ON MILL CREEK, ONTARIO

INTRODUCTION

The recovery of stream ecosystems after highway construction often begins quickly after the completion of construction (Whitney and Bailey 1959; Edlington 1969; Barton et al. 1972; Burns 1972; Peterson and Nyquist 1972; Narver 1972; Burton et al. 1976; Barton 1977; Extence 1978). However, only Taylor and Roff (1986) have reported a longer-term study on such recovery. In a study six years after the completion of highway construction over a stream, they found lingering impacts on bed load, invertebrate communities and fish communities.

This study continues previous work by Mathers (1978a, 1978b) on the impacts of construction of the Hanlon Expressway on Mill (Galt) Creek, Ontario. Mathers (1978a) examined fish and invertebrate populations, water quality and sediment load upstream and downstream, before (1972-1973), during (1974-1975) and after (1975-1976) the highway construction, to determine the effectiveness of erosion control methodology. He found that biomass and density of total fish and brook trout (*Salvelinus fontinalis*) declined during construction at downstream stations and did not return to pre-construction levels even one year after the completion of the study. Invertebrate density was unaffected by highway construction. However, shifts in invertebrate community structure were noted. During construction, suspended solids and bed load increased at downstream stations. The increased suspended solids were rare events, associated with runoff from storm events or instream channel work but, when observed, these increases were often substantial. Sodium and Cl were also elevated and associated with snow meltwater after completion of construction. Heavy metals, nutrients and other water quality parameters were unaffected by highway construction.

Our purpose in this study was to determine any long-term impacts related to the highway construction at Mill Creek.

Accordingly, we collected additional data at the original stations on fish and invertebrate populations, water quality and sediment loading during 1985, and compared them with unpublished data collected by Mathers (1978b).

STUDY AREA

The study stream is a tributary to Mill (Galt) Creek (latitude $43^{\circ}27'14''N$, longitude $80^{\circ}10'48''W$) which, in turn, flows into the Grand River at Cambridge, Ontario (Fig. 1). The study stream has two branches, the confluence of which was relocated by the construction of the Hanlon Expressway (Highway #6). Mathers (1978a, 1978b) described in detail how the stream was relocated and the mitigation procedures used during the construction.

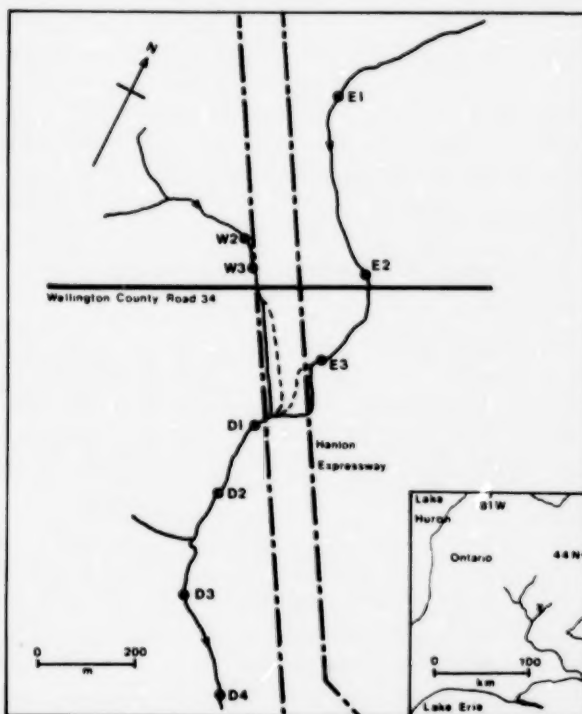


Fig. 1. Location of the study area sampling stations at Mill Creek, Ontario. The original stream channel prior to relocation is indicated with-----.

Data were collected at six of Mather's original stations along Mill Creek (Fig. 1). Four stations were located downstream of the highway construction (D1, D2, D3 and D4), and two were located upstream, one on the west branch (W2) and one on the east branch (E3).

This tributary of Mill Creek is relatively low in gradient (7 m km^{-1}). Summer base flow is about $0.05 \text{ m}^3 \text{ s}^{-1}$ and maximum recorded flow is $0.64 \text{ m}^3 \text{ s}^{-1}$ at D3 (Mathers 1978a). Therefore, flooding is relatively minor and, accordingly, the flow is extremely stable. In the study area, the stream flows through a white cedar (*Thuja occidentalis*) swamp. The soils primarily are poorly drained organic muck overlying a layer of marl (Mathers 1978a).

METHODS

For the most part, our data were collected at the same stations used by Mathers (1978a). However, Mathers (1978a) included several additional stations, but at no station did he collect all types of data. Because he found sites similar within an upstream or downstream section, we have chosen one representative station from each upstream branch and two downstream stations

for the collection of most of our data. The stations that we and Mathers (1978a) used for each type of data are listed in Table 1.

BED LOAD

Bed load was measured weekly from June to October 1973 to 1975 and 1985, and during June to July 1976. As bed load moved downstream it was sampled with two or three small glass jars, placed in collars buried in the stream bed at D1, D4, W2 and E1 or E3. (E1 was used from 1973 to 1976; E3 provides a better spatial control and replaced E1 during 1985.) During 1973 to 1976, jars (volume = 210 ml, diameter = 4.4 cm) were placed with the lip protruding about 2 cm above the stream bed (Mathers 1978a). Because the protruded lip caused the jar to underestimate the bed load, jars (volume = 240 ml, diameter = 4.8 cm) were placed with lips flush with the stream bed during 1985. As well, we used both of these methods to estimate a conversion equation between the two jar samples:

$$A = 1.4740 \times B + 4.348 \quad (R^2 = 0.953)$$

where A is g of bed load captured by a jar used during 1985 and B is g of bed load captured by a jar used during 1973 to 1976, set for the same elapsed time.

Table 1. Comparison of locations for data collection between this study and in Mathers (1978a) at Mill Creek.

Type of data	Location	
	This study	Mathers (1978a)
Bed load	W2, E3, D1, D4	W2, E1, D1, D4
Bed load size distribution	D1, D2, D3, D4	-
Benthic invertebrates	W2, E3, D1, D4	W2, E3, D1, D4
Fish	W2, E3, D1, D4	W2, E3, D1, D4
Suspended solids	W2, E3, D1, D4	W3, E2, D1, D3
Water quality	W2, E3, D1, D4	W2, E3, D1, D4

Bed load samples were oven dried to a constant weight, weighed to determine dry weight, and then ashed for one hour at 500°C and reweighed to determine organic content. For consistency with the data of Mathers (1978b), we analyzed all bed load data as monthly means.

The size distribution of the bed load was determined at D1, D2, D3 and D4 from samples taken during one week in October 1985. Bed load material was mechanically sieved through the following size mesh (µm): 2000, 900, 400, 250, 150, 110, 75 and 45. The filtrate was then filtered through Whatman GF/C glass fibre filters. Sized samples were dried and ashed as above. The composition of bed material was estimated visually by size (Dodge et al. 1985) in 25 m sections from D4 to W2 and E3.

BENTHIC INVERTEBRATES

Benthic invertebrates were sampled during spring (May or June) and fall (September to November) from fall 1972 to spring 1976, and during spring and fall 1985 at D1, D4, W2 and E3. During 1972 to 1976, five replicate samples were taken at each station with a Surber sampler (0.093 m²) with mesh of 12 threads cm⁻¹ and then washed through a 0.5 mm sieve (Mathers 1978a). During 1985, 10 replicate random samples, stratified by area, were taken with a T-sampler (0.0081 m²) with 0.5 mm mesh. Makie and Bailey (1981) found no difference in sampling efficiency between these two samplers. Invertebrates were sorted alive, preserved, and later counted and identified.

Invertebrate diversity was calculated on the pooled replicates using the following formula (Shannon and Weaver 1949):

$$d = -\sum n_i/N \log_2 (n_i/N)$$

where d is invertebrate diversity, N is the total number of organisms, and n_i is the number of organisms in taxon i .

FISH

Fish biomass and density were estimated during spring (May or June), summer (August or September) and fall (October) during 1973, 1974 and 1975, and during

spring and summer during 1976 and 1985 at D1, D4, W2 and E3. At each station, 25 to 40 m of stream was blocked with seine nets (1 cm mesh) and then successively electrofished 3 to 6 times (Dodge et al. 1985). Fish were kept alive in buckets until identified, measured (fork length), weighed and released. Density and biomass estimates were made using the method of Zippen (1958).

WATER QUALITY

Water temperatures were measured with maximum and minimum recording thermometers weekly from the last week in May to the third week in October during 1973 to 1975, and 1985 at D1, D4, W2 and E3.

Dissolved oxygen, % oxygen saturation, total nitrogen, nitrate nitrogen, total phosphorus, orthophosphate, pH, alkalinity, total dissolved solids, Ca, Mg, Na, K, Cl, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn were measured monthly from June to October or November during 1973 to 1975 and 1985, and from June to July 1976 at D1, D4, W2 and E3. See Mathers (1978a) for methods used during 1973 to 1976. During 1985, these water quality parameters were analyzed according to procedures outlined by the Ontario Ministry of the Environment (1981). Mathers (1978a) used the same techniques.

Suspended solids were also measured during the same time period and at the same stations during 1985. However, during 1973 to 1976, measurements of suspended solids were made at D1, D3, W3 and E2. We have treated D3 as D4, W3 as W2 and E2 as E3 in our analyses. Sites within these pairs of stations are relatively close in proximity (Fig. 1).

DATA ANALYSIS

Green (1979) suggested that the optimum stream impact study should have temporal and spatial controls by collecting data before and after, and upstream and downstream of the potential impact. Impacts on streams generally occur only downstream from a point of disturbance and so upstream areas can be used as spatial controls (Green 1979). With this design, an impact on some variable should be detected at a station

if the variable increases or decreases through time compared with the spatial controls. Such a condition can be determined with the spatial and temporal interaction term in an analysis of variance (ANOVA) of the variable. In our case, the null hypothesis of no impact on a variable can be rejected with a statistically significant interaction term of a two-way ANOVA of station and year effects; and then, if the trends of the variable are consistent with the impact hypothesis, as determined by one-way ANOVA for each of station and year, the impact hypothesis should be accepted.

We followed Green's approach for all but fish population variables. Since fish are highly mobile, the upstream controls may not be independent of the downstream stations. Accordingly, for fish, a significant interaction of station and year effects was not an effective test of the impact hypothesis. Rather, for fish, we examined the trends of the year effect.

In this study, we used $\alpha = 0.05$ for the probability level of significance.

RESULTS

BED LOAD

The highway construction has caused elevated bed load in Mill Creek. Consistent with the impact hypothesis, the two-way ANOVA of station and year effects for bed load indicated a significant interaction between the main effects (Table 2). Before construction, the total and inorganic bed load did not differ significantly among stations (Fig. 2A and 2B), and at only W2 was the organic bed load significantly greater than at the other stations (Fig. 2C). Total, inorganic and organic bed loads did not differ significantly at the two upstream stations (W2 and E3) except that inorganic bed load was higher during 1973 at E3. This difference at E3 was not large and was not important to the hypothesis tested here. However, total inorganic and organic bed load increased significantly at D1 during and after construction. Moreover, at D1, all bed load measures went from the lowest of any

station in 1973 to the highest in 1985 (Fig. 2). The impacts on bed load observed at D1 did not extend downstream to D4.

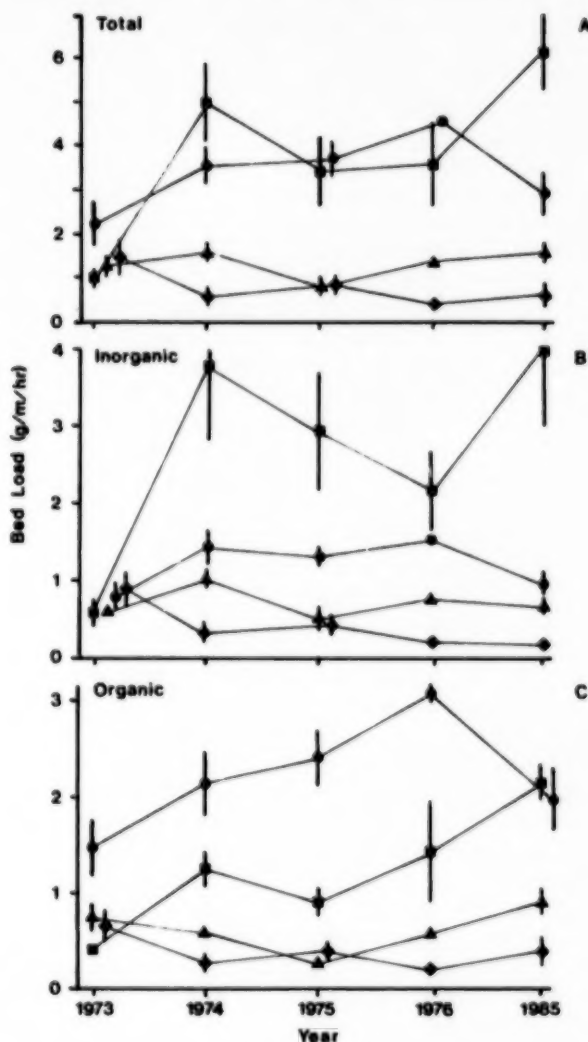


Fig. 2. Mean bed load in each year for each station at Mill Creek. A - total bed load. B - inorganic bed load. C - organic bed load. The vertical bars indicate one standard error either side of the mean. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

The source of the elevated bed load at D1 appeared to be exposed marl beds in the west stream relocation channel (Fig. 1). The percent loose marl (estimated in the sand size class 0.0625-1.0 mm) in the stream bed declined downstream of

Table 2. Results of two-way analysis of variance for station and year effects on variables studied at Mill Creek.

Variable	Probability		
	Station	Year	Station x year
Total bed load	0.001	0.003	0.001
Inorganic bed load	0.016	0.001	0.001
Organic bed load	0.001	0.001	0.001
Invertebrate density	0.062	0.255	0.001
Fish biomass	0.001	0.001	0.038
Fish density	0.001	0.003	0.868
Brook trout biomass	0.022	0.003	0.101
Brook trout density	0.001	0.040	0.206
Maximum temperature	0.056	0.001	0.153
Minimum temperature	0.001	0.135	0.211
Mean temperature	0.128	0.014	0.419
Alkalinity	0.085	0.052	0.997
pH	0.067	0.001	0.988
Oxygen	0.009	0.013	0.833
% oxygen saturation	0.006	0.385	0.668
Total dissolved solids	0.273	0.002	0.998
Total nitrogen	0.429	0.008	0.476
Nitrate nitrogen	0.001	0.706	0.240
Total phosphorus	0.023	0.040	0.544
Orthophosphate	0.033	0.108	0.346
Sodium	0.001	0.001	0.001
Chloride	0.001	0.001	0.037
Calcium	0.912	0.552	0.590
Magnesium	0.122	0.002	0.610
Potassium	0.063	0.001	0.620
Cadmium	0.100	0.001	0.250
Chromium	0.984	0.001	0.949
Copper	0.714	0.001	0.992
Iron	0.656	0.001	0.990
Manganese	0.866	0.001	0.994
Nickel	0.713	0.001	0.456
Lead	0.902	0.001	0.973
Zinc	0.645	0.116	0.731

the west relocation channel (Fig. 3). In the east relocation channel and upstream from the west channel, the marl content is near zero. ANOVA indicated this decline better fitted a third order equation (Fig. 3) rather than first or second order equations. Thus, the decline was not constant, but rather a sharper decline in the marl content of the substrate was found about 250 m downstream from the source. This was further substantiated by more detailed analysis of the bed load size distribution. The size distributions of the bed load collected at D1, D2, D3 and D4 indi-

cated a continuous mass of marl moving downstream. The size distributions of the inorganic bed load were not significantly different at D1 and D2, and at D3 and D4, but the size distribution of the inorganic bed load at D1 or D2 was significantly smaller than at D3 or D4 (Fig. 4A). The larger size categories of the inorganic bed load were responsible for most of these differences, and these size categories held most of the loose marl. The organic bed load was not different in size among all of these stations (Fig. 4B).

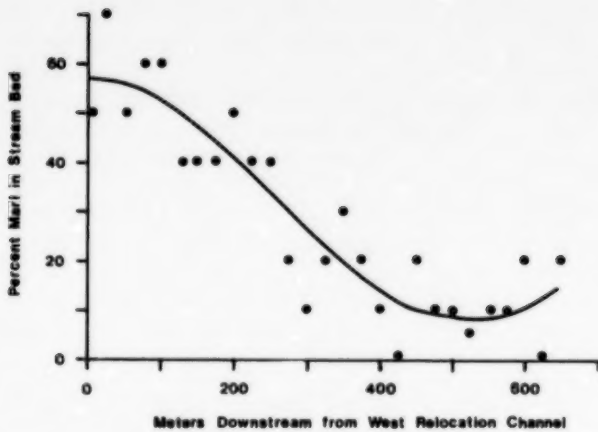


Fig. 3. Marl content of the stream bed downstream from the stream channel relocation at the west branch of Mill Creek during October 1985. The fit to the observed data is given by $Y = 56.8 - X^2 \times 5.55 \times 10^{-4} + X^3 \times 7.12 \times 10^{-7}$, where Y is the % marl in the stream bed and X is the meters downstream from the west relocation channel

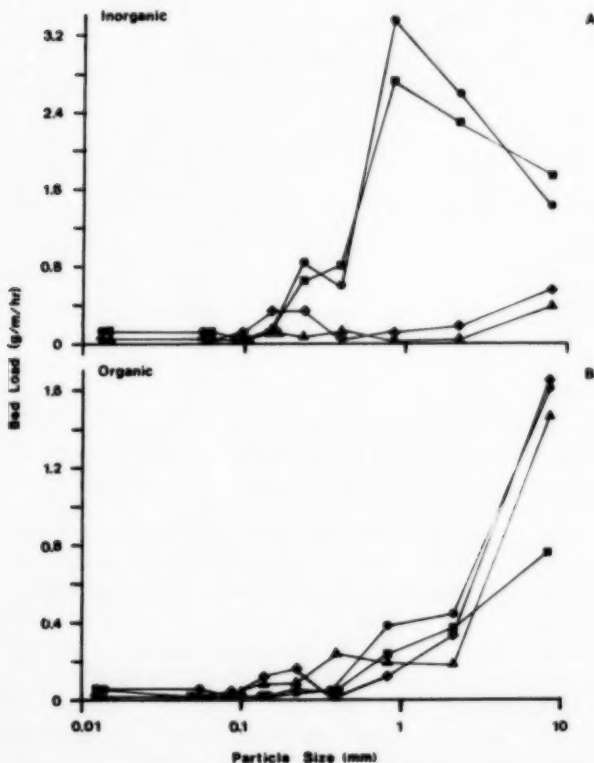


Fig. 4. Size distribution of bed load material in Mill Creek during October 1985. A - inorganic bed load. B - organic bed load. Symbols indicate stations: square - D1; circle - D2; diamond - D3; triangle - D4.

In conclusion, we have observed a mass of marl moving downstream from the construction site as a slug. Based on 10 years since the marl beds were exposed, the eroded marl has moved downstream at a rate of about 25 m yr^{-1} .

BENTHIC INVERTEBRATES

Only at D1, and only recently, has invertebrate density been impacted by the highway construction. Initial analyses indicated no effect of season on invertebrate density, and so subsequent analyses combined seasons. Consistent with our impact hypothesis, the two-way ANOVA of station and year effects for invertebrate density indicated a significant interaction between the main effects (Table 2). Furthermore, in subsequent analyses of invertebrate density, three patterns have emerged. First, from 1972 to 1976, there was relatively little change in the pattern of invertebrate density at all stations (Fig. 5). Second, invertebrate density at D1 was significantly lower during 1985 than other years, except 1972. This pattern of invertebrate density is consistent with the rate of downstream movement of loose marl originating from the west relocation channel. This channel was opened during 1975, and so the marl slug would not have moved downstream to the point where invertebrates were sampled at D1 during 1975 or 1976. Third, during 1985, invertebrate density was significantly greater than earlier samples at E3 and D4, and also was ranked highest at W2.

The smaller T-sampler was used during 1985, instead of a Surber as used previously. Although Makie and Bailey (1981) have shown there is no difference in sampling efficiency between these samplers, we believe invertebrates from the smaller samples obtained by the T-samplers were more efficiently sorted from the debris in the sample, because this job is tedious and becomes monotonous with larger samples. Accordingly, if the 1985 samples from D1 were also biased upwards relative to previous years, then the impacts on invertebrate density at D1 were greater than indicated above.

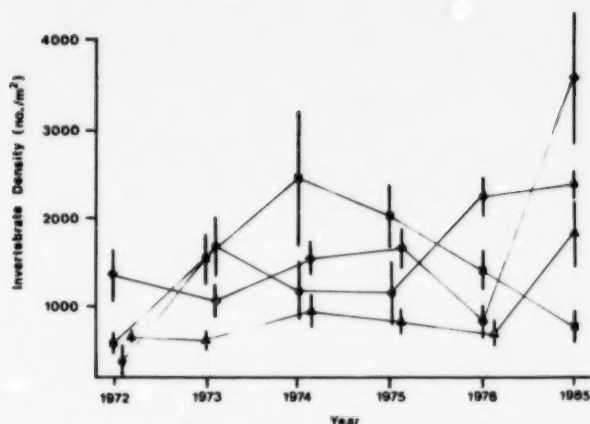


Fig. 5. Mean invertebrate density in each year for each station at Mill Creek. The vertical bars indicate one standard error either side of the mean. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

Invertebrate diversity was not impacted by highway construction, since the interaction between station and year effects in a two-way ANOVA was not significant (Table 2).

FISH

Fish populations in Mill Creek were impacted by highway construction after the construction ended. The interaction effect in a two-way ANOVA of station and year effects was significant for total fish biomass, but not for total fish density, or brook trout biomass or density (Table 2). However, the year effects were significant for these latter variables (Table 2).

At D1, fish biomass was lower in the post-construction period (1975, 1976 and 1985). Fish biomass was not significantly different during the study at each of W2, E3 and D4 (Fig. 6A), and across stations during 1973, 1974 and 1976. Trends in fish biomass at the other stations were similar to trends at D1, except at D4 during 1985 where fish biomass increased over other stations. This increase appears to be related to an increase in brown trout (*Salmo trutta*) which may have entered the niche vacated by brook trout during the highway construction. Fish density followed a

similar trend to fish biomass, and was significantly lower during 1975 and 1976 than 1973 (Fig. 6B). However, during 1985, fish density was not different from that during 1973.

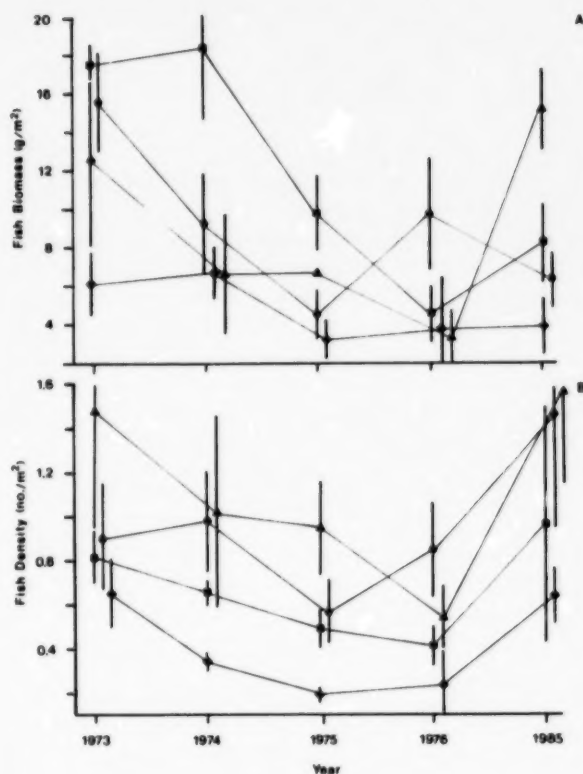


Fig. 6. Mean fish biomass and density in each year for each station at Mill Creek. A - fish biomass. B - fish density. The vertical bars indicate one standard error either side of the mean. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

Brook trout biomass was also significantly lower during 1975 and 1976 than in 1973 and 1974 (Fig. 7A), but during 1985, brook trout biomass was not different from all other years. Brook trout density did not differ significantly from 1973 to 1976 (Fig. 7B), but during 1985, brook trout density was greater than in all other years except 1974. This increase in density without a comparable increase in biomass means that the average length of brook trout was smaller in Mill Creek during 1985 than in the previous years.

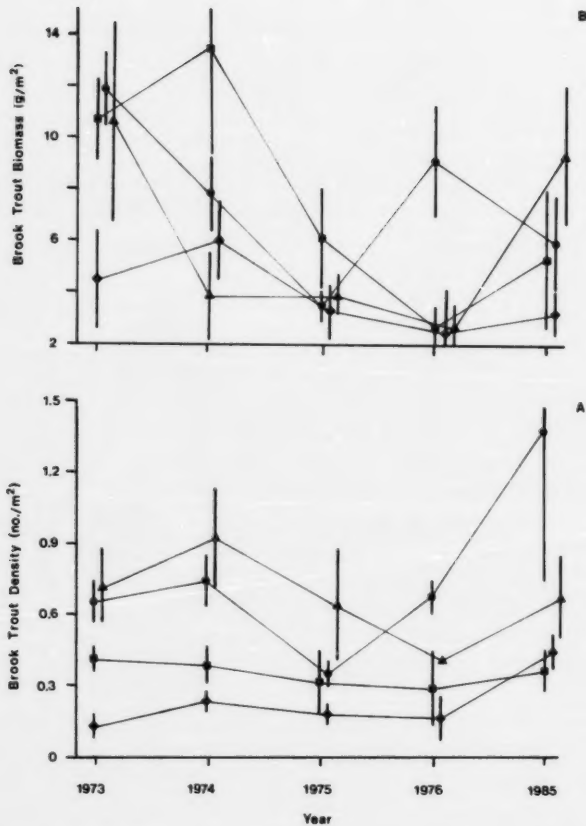


Fig. 7. Mean brook trout biomass and density in each year for each station at Mill Creek. The vertical bars indicate one standard error either side of the mean. A - brook trout biomass. B - brook trout density. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

Brook trout growth rates at all stations showed no trends consistent with impacts of highway construction on their invertebrate food (Fig. 8; estimates of growth rate for D1 in 1973 and E3 in 1974 were not significant and are not shown here). On the contrary, growth rates at D1 increased significantly between 1974 and 1985, and at W2 increased significantly from pre-construction to post-construction years. Furthermore, at D1 and W2, growth rates which were significantly lower than at E3 and D4 during 1973 and 1974 were not significantly different in later years.

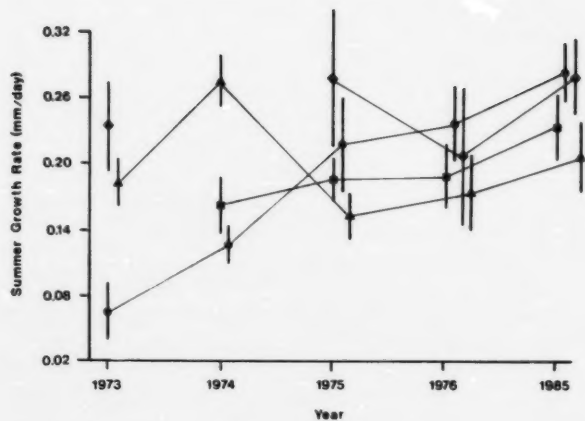


Fig. 8. Brook trout growth rate in each year for each station at Mill Creek. The vertical bars indicate one standard error either side of the mean. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

WATER QUALITY

Of all the water quality variables examined, only Na and Cl appear to be elevated in a manner consistent with highway construction. We could detect no impacts consistent with highway construction on all other variables, because the interactions between station and year effects in two-way ANOVA were not significant (Table 2).

Sodium and Cl followed similar trends at all stations (Fig. 9). Concentrations of these ions were greater at all stations during 1985, and these differences were significantly greater for all stations except Cl at D4. Sodium at D1 was also significantly greater in 1976. The increases in these ions at the downstream stations were paralleled by increases at E3, but not W2. Thus, part of the increase in Na is not attributable to the Hanlon Expressway at the vicinity of the stream crossing. Apparently there are other sources of Na and Cl in the watershed of the east branch above E3. On the other hand, we should expect some reasonable dilution effect from the west branch at the downstream stations. Since such a dilution was not observed, we conclude that the Hanlon Expressway must contribute to the elevated Na and Cl at the downstream stations.

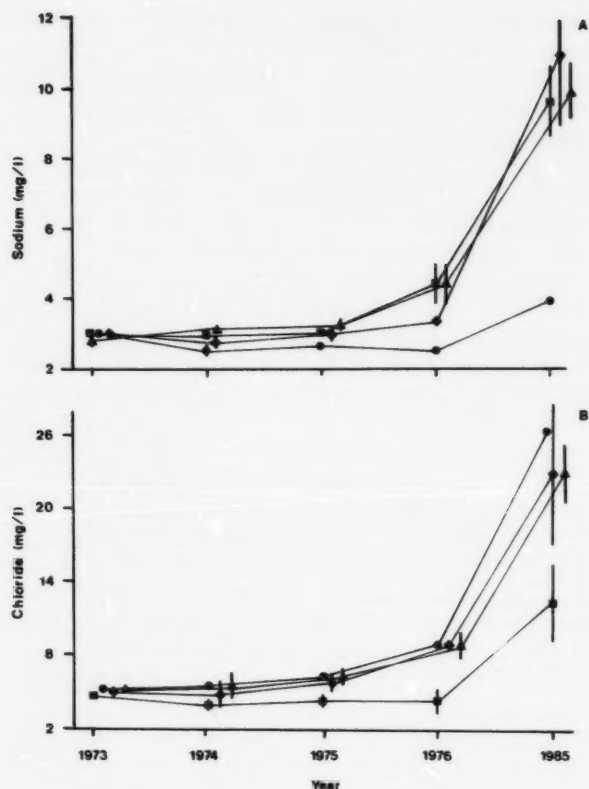


Fig. 9. Mean Na and Cl concentration in each year for each station at Mill Creek. The vertical bars indicate one standard error either side of the mean. A - Na. B - Cl. Symbols indicate stations: circle - W2; diamond - E3; square - D1; triangle - D4.

DISCUSSION

The primary long-term impact of highway construction on Mill Creek is currently the elevated bed load eroding from marl beds in the west stream relocation channel. The zone of impact is relatively small. However, left unchecked, the slug of loose marl should reach D4 by about the year 2000 and mainstream Mill Creek by about the year 2010.

The invertebrate and fish populations appear to be secondarily affected by the highway construction through the slug of loose marl in the bed load. The loose marl has covered habitat for both invertebrates and fish. The marl is similar to sand in size and, accordingly, should be comparable to sand in habitat quality.

Thus, it is not surprising to see lower invertebrate densities in areas covered with loose marl. Invertebrate densities are commonly lower in sand habitats, a result, in part, of the shifting and abrasive nature of sand (Brusven and Prather 1974; Williams 1978).

The covering of the stream bed by this slug of marl has covered pools and in-stream cover for fish. Accordingly, there still is a reduced fish biomass and fish smaller than average size at D1. Habitat for larger fish has been lost. Although fish biomass at D4 has returned to pre-construction levels, the marl slug should have a similar covering effect on fish and invertebrate habitat and populations at D4. Saunders and Smith (1965) also found low brook trout populations when instream cover in a stream was overlaid by silt. However, after the silt was flushed from the stream, they found that trout populations increased. More recent work by Alexander and Hansen (1986) indicates marked reductions in brook trout numbers and habitat. The reduction in the trout population was a response to poorer habitat and the affect was a decrease in survival rates in the egg-fry and/or the fry-fingerling life stages. They also found this reduction in population to occur for aquatic invertebrates as well. Alexander and Hansen (1983) found that trout numbers increased significantly after a reduction in sand bed load.

It is interesting that fish and brook trout density and brook trout biomass were lower at control stations after construction. This supports our earlier conjecture that fish populations above and below the construction were not disjunct. Rather, movements between these contiguous areas resulted in measurable declines at all stations. Perhaps during 1975 and 1976, some fish may have moved downstream to mainstream Mill Creek. This reduction in fish may have been related to the periodic increases in suspended solids downstream from construction activities (Mathers 1978a).

An expected decline in growth rate of brook trout at D1, related to the decline in invertebrate density was not observed. Rather, these growth rates increased along with growth rates at W2.

This increase may be related in a "density-dependent" fashion to the lower fish biomass that we observed at these stations. Alternatively, invertebrate production at these stations may have increased due to improvements in the quality of their food as shown in other studies (Taylor and Roff 1986). Certainly, the increased exposure of the stream to the sun, as a result of the construction, offers increased opportunities for higher primary production immediately above D1. However, this cannot explain increased growth rates at W2. Patterns of temperature or nutrient concentrations did not explain increased trout growth rates either directly or through influences on lower trophic levels.

Although Mathers (1978a) observed increased suspended solids downstream from highway construction, we were unable to detect this effect using a subset of his data. Mathers collected his data weekly, whereas we used only one of his values from each month. High suspended solids occurred rarely and on days that we did not select for analysis (Mathers 1978b).

Sodium and Cl increases were probably caused by the use of deicing salt on roads during winter. Since the data here were collected during summer, these higher concentrations reflect increases in Na and Cl in groundwater. McConnell and Lewis (1973) suggested that 20 to 50% of road salt may infiltrate into the groundwater. The other 50 to 80% would run off into the stream during winter when we did not sample. Mathers (1978a) found highest concentrations of Na and Cl in Mill Creek during winter. However, Kunkle (1972) found highest concentrations of Na and Cl in a Vermont stream during August. Considering the patterns of the biological parameters measured here, we can detect no influence of road salt on the invertebrate and fish populations in Mill Creek. Moreover, although road salt may cause heavy metals such as mercury, nickel, chromium, iron and zinc to be released from sediments (Feick et al. 1972; Hedley and Lockley 1975), we found no change in heavy metal concentration consistent with this effect. Therefore, we do not consider the current Na and Cl levels to be serious to aquatic life.

Complex changes and adjustments within the aquatic community are obviously still taking place in Mill Creek. The elevated bed load since highway construction is affecting the numbers and average size of fish in the affected area. Fish biomass has returned to pre-construction levels in the lower treatment station at D4, but the long-term effect of the slug of marl has not been felt yet at this station. If the mobile slug of marl was not present, it is likely that the fish and invertebrates would have recovered to pre-construction levels at D1.

Complex changes in the invertebrate and fish community also occurred in Hanlon Creek, Ontario, after highway construction (Taylor and Roff 1986). The long-term results of Taylor and Roff (1986) indicated that although diversity of the invertebrate and fish community had rebounded six years after construction, the structure of the invertebrate community had changed. The aquatic community of Hanlon Creek appears to be still changing, as a result of permanent increases in nutrient and sediment loadings, originally the result of highway construction and now maintained by urbanization of the upper drainage. Urbanization is not a factor on Mill Creek. However, the exposure of the marl bed in the west branch, and the possible increased primary production in the east branch, may continue to affect the aquatic community of Mill Creek.

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REFERENCES

- ALEXANDER, G. R., and E. A. HANSEN. 1983. Sand sediment in a Michigan trout stream. Part II. Effects of reducing sand bedload on a trout population. *North Am. J. Fish. Manage.* 3: 365-372.
- ALEXANDER, G. R., and E. A. HANSEN. 1986. Sand bedload in a brook trout stream. *North Am. J. Fish. Manage.* 6: 9-23.
- BARTON, B. A. 1977. Short-term effects of highway construction on the limnology of a small stream in southern Ontario. *Freshw. Biol.* 7: 99-108.
- BARTON, J. R., D. A. WHITE, P. V. WINGER, and E. J. PETERS. 1972. The effect of highway construction on fish habitat in the Weber River, near Henefer, Utah. *Eng. Resour. Centre, CO Bur. Reclam. REC-ERC-72-17: 17-28.*
- BRUSVEN, M. A., and K. V. PRATHER. 1974. Influence of stream sediments on distribution of macrobenthos. *J. Entomol. Soc. B.C.* 71: 25-32.
- BURNS, J. W. 1972. Some effects of logging and associated road construction on northern California streams. *Trans. Am. Fish. Soc.* 101: 1-17.
- BURTON, T. M., R. R. TURNER, and R. C. HARRIS. 1976. The impact of highway construction on a north Florida watershed. *Water Resour. Bull.* 12: 529-538.
- DODGE, D. P., G. A. GOODCHILD, J. C. TILT, and D. G. WALDRIFF. 1985. Manual of instructions, aquatic habitat inventory surveys. *Ont. Min. Nat. Resour., Toronto, Canada. Ms Rep.* 168 p.
- EDLINGTON, J. R. 1969. The impact of logging on the ecology of two trout streams in northern Idaho. M.Sc. thesis, Univ. Idaho, Moscow, ID. 73 p.
- EXTENCE, C. A. 1978. The effects of a motorway construction on an urban stream. *Environ. Pollut.* 17: 245-252.
- FEICK, G., R. A. HORNE, and D. YEAPLE. 1972. Release of mercury from contaminated freshwater sediments by the runoff of road deicing salt. *Science* 175: 1142-1143.
- GREEN, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York, NY. 257 p.
- HEDLEY, G., and J. C. LOCKLEY. 1975. Quality of water discharged from an urban motorway. *Water Pollut. Control* 74: 659-674.
- KUNKLE, S. H. 1972. Effects of road salt on a Vermont stream. *J. Am. Water Works Assoc.* 65: 290-295.
- MAKIE, G. L., and R. C. BAILEY. 1981. An inexpensive stream bottom sampler. *J. Freshw. Ecol.* 1: 61-69.
- MATHERS, J. S. 1978a. The effects of highway construction on Galt Creek, Ontario. Vol. I. *Ont. Min. Nat. Resour., Toronto, Canada. Ms Rep.* 115 p.
- MATHERS, J. S. 1978b. The effects of highway construction on Galt Creek, Ontario. Vol. 2. *Ont. Min. Nat. Resour., Toronto, Canada. Ms Rep.* 230 p.
- MCCONNELL, H. H., and J. LEWIS. 1973. Add salt to taste. *Environment* 14: 38-44.
- NARVER, D. W. 1972. A survey of some possible effects of logging on two eastern Vancouver Island streams. *Fish. Res. Board Can. Tech. Rep.* 323: 1-55.
- ONTARIO MINISTRY OF THE ENVIRONMENT. 1981. Outline of analytical methods. *Lab. Serv. Br.* 246 p.
- PETERSON, L. A., and D. NYQUIST. 1972. Effects of highway bridge construction on a subarctic stream. *North. Eng.* 4: 18-20.
- SAUNDERS, J. W., and M. W. SMITH. 1965. Changes in a stream population of brook trout associated with increased

- silt. J. Fish. Res. Board Can. 22: 395-404.
- SHANNON, C. E., and W. WEAVER. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana, IL.
- TAYLOR, B. R., and J. C. ROFF. 1986. Long-term effects of highway construction on the ecology of a southern Ontario stream. Environ. Pollut. Ser. A Ecol. Biol. 40: 317-344.
- WHITNEY, A. N., and J. E. BAILEY. 1959. Detrimental effects of highway construction on a Montana stream. Trans. Am. Fish. Soc. 88: 72-73.
- WILLIAMS, D. D. 1978. Substrate size selection by stream invertebrates and the influence of sand. Limnol. Oceanogr. 23: 1030-1033.
- ZIPPEN, C. 1958. The removal method of population estimation. J. Wildl. Manage. 22: 82-90.

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